# Egg production and welfare of laying hens kept in different housing systems (conventional, enriched cage, and free range)

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**ABSTRACT** The aim of this study was to compare egg production performance and welfare traits of laying hens kept in conventional cage (CC), enriched cage (EC), and free range (FR). Lohmann Brown laying hens (n = 480 with 160 per housing type) were studied across a production cycle from placement at 17 wk until depopulation at 66 wk. The hens were randomly allocated into cages or pens of housing system groups; within each system there were four replicates with 40 hens in each pen or cage. The hen day egg production ($P = 0.037$), feed intake (FI) ($P < 0.001$), egg mass (EM) ($P < 0.001$), and dirty egg ratio of hens were higher in the FR system but similar in the CC and EC systems. The highest mortality ratio was found in EC system hens ($P = 0.020$). The best feather score was found in FR system hens ($P < 0.001$). The worse body wound score was found in EC system hens ($P = 0.038$). On the other hand, the worse bumble foot and footpad lesions were found in FR system hens ($P < 0.001$). The highest tibia breaking strength was found in FR system hens compared with in CC and EC system hens ($P < 0.001$). The highest Heterophil/Lymphocyte (**H/L**) ratio was found in CC system hens ($P = 0.006$) but the blood phosphorus (**P**) level was higher in FR system hens ($P = 0.013$). The tonic immobility, blood glucose, total cholesterol, triglyceride, and Ca values of hens were found to be similar in all systems ($P > 0.05$). The hens in the FR system had additional space for optimum comfort and better feather and bone traits, but the dirty egg ratio, feed consumption, and foot lesions were higher than in CC and EC systems.

**Key words:** conventional cage, enriched cage, free range, egg production, welfare

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## INTRODUCTION

Conventional cage systems were developed in the 1930s and used in traditional egg production since the 1950s. These systems have been around a long time and their sole purpose was to maximize profit and productivity with more hens being housed in a small area and higher egg production (Sosnowka-Czajka et al., 2010; Jones et al., 2014). However, in Europe during the 1960s, welfare of animals gained importance and conventional cage systems were questioned for restriction of movement, and certain behavior patterns of laying hens are affected by the small space and bare environment (Mench et al., 2011).

Enriched cages were first developed in Germany during the 1980s and have since been improved (Appleby, 1998). These cages are different from conventional cages which provide more space for each hen (750 $cm^2$ space per hen) and are equipped with a perch, nest, scratching area, and nail shortener (Lay et al., 2011). Following public concern about conventional cage systems for laying hens they were banned in the EU in 2012 and only enriched cages systems or noncage systems, such as aviaries, barn, free range, and organic systems are allowed in the European Union (EU Directive 1999/74/EC).

European animal welfare organizations have been campaigning against the enriched cages because hens are still in cages and do not have enough area for natural behavior, and some EU countries are considering banning also enriched cages in a near future (Mench et al., 2011). Also there is an interest in free range poultry farming in developed countries. One reason for this is welfare concern associated with farming of poultry under intensive conditions and the other reason is consumer concern. Today most consumers prefer to eat healthy eggs and there is a perception that free range eggs are healthier than those are obtained from cage systems (Miao et al., 2005). The free range system, known as a backyard system, was dominantly used before the cage was invented until the 1920s. These systems are floor systems, which provide access to the outdoors and also provide more space for behavioral freedom to the hens (Mench et al., 2011).


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According to EU Directive (EU Directive 1999/74/EC) new trends in housing systems are becoming more common (Asselt et al., 2015) and researchers are evaluating different housing systems for production performance (Tactacan et al., 2009; Karcher et al., 2015) and health (Rodenburg et al., 2008; Lay et al., 2011) of hens. Therefore, the aim of the current study was to describe and compare egg production performance and welfare traits, such as body score, blood, and bone parameters of hens kept in different housing systems (conventional, enriched cage, and free range) systems.

## MATERIALS AND METHODS

The study was carried out on 480 layers (Lohmann Brown) between 17 and 66 wk of age, when hens were placed and depopulated, respectively. Three different housing systems **(HS)**; conventional cage **(CC)**, enriched cage **(EC),** and free range **(FR)**, were used in this study. Practices regarding the care and use of animals for research purposes were in accordance with the laws and regulations of Turkey and approved by the Animal Use and Ethical Committee of Uludağ University (Approval Number 2013-01/07).

### *Housing Systems and Description*

The CC, EC, and FR systems were located on the same research unit of Uludağ University. The CC and EC systems were installed in a windowed and fan ventilated cage hen house and both cage types placed in the same room. The FR system was located 120 m from the cage hen house. The physical characteristics of the housing systems are given in Table 1.

The CC system consisted galvanized wire cages with a nipple drinker, troughtype galvanized feeder, egg belt, and manure belt. A total floor area of 562.5 $cm^2$ was provided per hen in each CC cage.

The EC system cage units met the requirement of the EU Directive 1999/74/EC. These systems consisted of galvanized wire cage with nipel drinkers (8 nipples per cage), troughtype galvanized feeder (12 cm of feeder per hen), egg belt, and manure belt. The systems also had nail shorteners (8 nail shortener per cage), perches (18 cm of area per hen), nesting areas surrounded by an orange curtain (102 $cm^2$ per cage), and a green artificial turf scratch pad area (45.92 $cm^2$ per cage). A total floor area of 750 $cm^2$ was provided per hen in each EC cage.

The FR system had an indoor and pasture area. The floor was covered with wood shavings as a litter materal in the indoor area. The circular galvanized feeders and plastic drinkers were used in the indoor and pasture areas. The FR indoor area also had perches (15 cm of area per hen) and nest box (4 hens per nest). A total 7 hens per $m^2$ was provided in the FR system indoor area. The FR system pasture area was enclosed by wire fences to keep out predators and had a shelter. A total of 60% perennial ryegrass (Lolium perenne), 10% white clover (Trifolium repens), and 30% alfalfa (Medicago sativa) were sown in the pasture area. A total 8 hens per $m^2$ was provided in the FR system pasture area.

The photoperiod at the time of laying was 16L:8D in all of the systems. A standard commercial layer diet was used (17% CP and 2,750 ME kcal/kg for 18 to 40 wk; 16% CP and 2,700 ME kcal/kg; 0.7% P and 3% Ca for 41 to 66 wk) in all systems. The diets were formulated to National Research Council specifications (NRC, 1994). Feed and water were offered adlibitum to all hens. The minimum and maximum mean temperature and humidity values were 8.03 to 26.61°C and 57.46 to 81.71% in the FR system throughout the study period. The room temperature was between 18 and 23°C and humidity was 60 to 70% in the CC and EC system.

### *Management and Data*

Hens were randomly allocated into cages or pens of CC, EC, and FR system groups then weighed with a digital scale with a ± 0.1 g precision and wing numbers were attached. The body weights among groups were found to be similar ($P > 0.05$). A total of 160 hens were placed in each housing system with 4 sub-groups (n = 40 hen) defined as the replicates of each system. The laying hens were weighed individually at 17 wk of age and 66 wk of age.

All eggs were collected from each group daily and the hens were monitored until the end of the experiment. The hen daily egg production, number of damaged eggs, number of dirty eggs, and mortality were recorded daily. Feed intake **(FI)** and egg weight **(EW)** were recorded weekly. Egg production (**EP**) was calculated by dividing the number of daily eggs by the number of hens on the same day. Based on daily egg production; the 5%, 50%, and peak hen day egg production reach age of hens were determined. The ratio of damaged eggs in each group was calculated by dividing the number of damaged eggs by total eggs. The ratio of

**Table 1.** The physical characteristics of the housing systems.

| Characteristics | CC | EC | FR indoor | FR pasture area |
|---|---|---|---|---|
| Floor area | 562.5 $cm^2$/ hen | 750 $cm^2$/ hen | 7 hens / $m^2$ | 8 hens / $m^2$ |
| Egg Belt | Yes | Yes | No | No |
| Perch | No | Yes | Yes | No |
| Nest | No | Yes | Yes | No |
| Nail shortener | No | Yes | No | No |
| Scratching area | No | Yes | Yes | Yes |

dirty eggs in each group was calculated by dividing the number of dirty eggs by total eggs. Egg mass **(EM)** was calculated as EM = (EP∗EW)/100. The FCR was calculated as FCR = FI/EM. The data for EP, ratio of damaged and dirty eggs, FCR, and FI were calculated at 20, 30, 40, 50, and 60 wk of age.

### Welfare Traits

At 66 wks of age, 40 hens were randomly selected from each housing system and were inspected for feather condition, body wounds, bumble foot, foot pad lesions, and claw length. The feather condition, body wounds, and bumble foot were scored according to Tauson et al. (2005) and footpad lesions were scored according to Ekstrand et al. (1998) by the same person. The claw length on 4 toes of each foot was determined using a measuring tape. The 8 claw length measurements per hen were averaged to calculate the mean claw length (Hester et al., 2013).

Bone properties (weight, length, cortical area, breaking strength, weight length index of the left tibia, and dry matter, ash, Ca, and P content of the right tibia) were measured at the end of the trial. A total of 24 hens were randomly selected and weighed. The body weights among groups were found to be similar ($P > 0.05$). The hens were sacrificed through cervical dislocation; then, the tibiotarsus of both legs were removed and dissected. The left and right tibiotarsus bones were coded and kept frozen in at −20°C until measurement and analysis. The frozen left tibiotarsus bones were later placed at room temperature for 1 hour (Crenshaw, 1986). After thawing, the bones were checked for any residue of soft tissues and then held at 22°C for 7 d to allow for drying. After drying, the bone weights were measured with a digital scale (Model XB 4200C, Precisa Corp, Zurich, Switzerland), and the bone length was measured using a digital caliper (Model CDN-20C, Mitutoyo Corp, Aurora, IL). Physical bone characteristics were determined by a compression test to assess the bone strength (Crenshaw et al., 1981). Thus, the diaphyseal shaft was divided into 3 sections (proximal, mid, and distal) with a thickness of 1 cm using a fret saw. The cortical areas of each section were measured using the ImageJ (National Institutes of Health, Bethesda, MD) Image Processing and Analyzing Program. Compression tests were performed using a fully computerized UTEST tensile and compression testing machine (Model 7014, UTEST Corp, Ankara, Turkey) that was fitted with a 250 kN load cell. The crosshead movement was at 10 mm/min. The ultimate bone breaking force (Newtons, N) and stress (Megapascals, MPa) were determined for each tibiotarsus. The tibia weight index **(WLI)** was calculated by the following formula: WLI (mg/mm) = tibia weight (mg) / tibia length (mm). The right tibiotarsus bones were subsequently thawed, subjected to a temperature of 105°C for six hours and then defatted with hexane in a Soxhlet apparatus (Model SER148, Şimşek Laborteknik, Ankara, Turkey) for four hours. After the extraction of fat, the bones were dried once more in a forced-ventilation oven at 105°C for 16 hours to obtain the dry and defatted weights. Then, the bones were crushed and calcined in a muffle furnace at 600°C for two hours in order to determine the ash content. The percentage of tibia dry matter and ash calculations were based on the fat-free dry weight by the AOAC method 932.16 (AOAC International, 2005). Approximately 1 g of ash sample was then dissolved in 10 mL of $HNO_3$ and 10 mL of HCl and boiled for 10 min. The sample was filtered and diluted into a 50 mL flask. The ash was used to prepare a mineral solution by dissolving in an $HNO_3$ and HCl solution in its purest form (1:1) for concentrates. After obtaining this solution, the calcium and potassium contents in the tibias were obtained through Optical Emission Spectrometry with an Inductively Coupled Plasma source (ICP-OES) (Optima 2100 DV, Perkin Elmer Inc, Shelton, CT) (Araujo et al., 2012).

### Tonic Immobility (TI) and Blood Parameters

A total of 36 hens (12 hens per housing system) were tested individually for a tonic immobility (**TI**) reaction at 66 wk of age. To measure the duration of TI, hens were caught randomly and carried in to a seperate room. A few seconds after the hen was caught, a TI test was induced according to Ghareeb et al. (2014), and a maximum score of 600 seconds was given for the duration. The day after the TI test, blood samples were collected from each group (n = 12). One milliliter of EDTA blood samples were taken, and 2 blood smears per hen were collected immediately after drawing blood. After air drying, the slides were stained with May Grünwald and Giemsa stain (Clark et al., 2009). A total of 100 leucocytes (heterophils, eosinophils, basophils, monocytes, and lymphocytes) were counted once on each slide using a microscope with 100× magnification and oil immersion. The means of 2 slides were calculated for each hen. The H/L ratios were calculated using H/L = number of heterophils / number of lymphocytes. At 66 wk of age, blood samples were taken from 12 hens from each housing system to determine the serum total cholesterol, triglyceride, glucose, Ca, and P levels. Blood samples were taken from the wing vein and centrifuged at 3,000 rpm for 15 min, and the serum was removed in vacutainer tubes. The serum levels of total cholesterol, triglyceride, glucose, Ca, and P were determined using a Roche autoanalyzer (Cobas 6000 series C501 module, Roche Diagnostic, Indianapolis, IN) and Roche kits.

### Statistical Analysis

The parametric data (EP, FI, EM, and FCR) were analyzed with ANOVA using the PROC GLM procedure of statistical analysis software (SAS, 2013). The housing system and age were the main effects. The EP,

**Table 2.** The effect of the housing system and hen's age on hen day egg production, feed intake, egg mass, feed conversion ratio, damaged and dirty egg ratios.

| Housing system ([1]HS) | Hen day egg production (%) | FI (g) | FCR, (g feed/g egg) | EM (g) | Damaged egg ratio (%) | Dirty egg ratio (%) |
|---|---|---|---|---|---|---|
| CC | 87.10$^{b}$ | 117.06$^{b}$ | 2.08$^{b}$ | 56.80$^{b}$ | 0.79$^{b}$ | 0.68$^{b}$ |
| EC | 87.26$^{b}$ | 118.06$^{b}$ | 2.11$^{a,b}$ | 56.66$^{b}$ | 1.20$^{a}$ | 0.83$^{b}$ |
| FR | 89.27$^{a}$ | 124.58$^{a}$ | 2.17$^{a}$ | 59.76$^{a}$ | 0.35$^{c}$ | 3.30$^{a}$ |
| SE | 0.87 | 0.56 | 0.02 | 0.34 | 0.07 | 0.15 |
| Age, wks of age (A) | | | | | | |
| 20 wk | 70.98$^{d}$ | 107.51$^{d}$ | 2.36$^{a}$ | 48.57$^{c}$ | 0.83$^{b}$ | 1.29$^{b}$ |
| 30 wk | 96.59$^{a}$ | 116.32$^{c}$ | 1.95$^{d}$ | 59.67$^{a,b}$ | 0.45$^{b}$ | 1.82$^{b}$ |
| 40 wk | 94.57$^{a,b}$ | 123.60$^{b}$ | 2.03$^{c,d}$ | 61.16$^{a}$ | 0.63$^{b}$ | 2.65$^{a}$ |
| 50 wk | 91.93$^{b}$ | 127.36$^{a}$ | 2.13$^{b}$ | 60.02$^{a,b}$ | 0.74$^{b}$ | 1.87$^{a,b}$ |
| 60 wk | 85.30$^{c}$ | 124.73$^{a,b}$ | 2.11$^{b,c}$ | 59.28$^{b}$ | 1.25$^{a}$ | 0.39$^{c}$ |
| SE | 1.12 | 0.73 | 0.02 | 0.44 | 0.10 | 0.20 |
| HS × A | | | | | | |
| CC 20 wk | 69.15 | 96.51$^{e}$ | 2.11$^{b–e}$ | 47.75$^{e}$ | 0.58$^{c–e}$ | 0.98$^{d,e}$ |
| 30 wk | 96.55 | 112.50$^{d}$ | 1.91$^{e}$ | 58.90$^{c,d}$ | 0.38$^{d,e}$ | 1.16$^{d,e}$ |
| 40 wk | 94.79 | 123.87$^{a,b}$ | 2.04$^{b–e}$ | 60.96$^{a–c}$ | 0.68$^{b–e}$ | 0.62$^{d,e}$ |
| 50 wk | 90.39 | 126.81$^{a}$ | 2.18$^{b}$ | 58.30$^{c,d}$ | 0.86$^{b–e}$ | 0.44$^{d,e}$ |
| 60 wk | 84.61 | 125.64$^{a,b}$ | 2.16$^{b–d}$ | 58.11$^{c,d}$ | 1.45$^{a,b}$ | 0.22$^{e}$ |
| EC 20 wk | 74.14 | 101.70$^{e}$ | 2.19$^{b}$ | 49.13$^{e}$ | 1.23$^{a–c}$ | 0.81$^{d,e}$ |
| 30 wk | 97.00 | 116.38$^{c,d}$ | 1.97$^{d,e}$ | 59.24$^{b–d}$ | 0.66$^{b–e}$ | 1.33$^{c–e}$ |
| 40 wk | 92.89 | 121.76$^{a–c}$ | 2.06$^{b–e}$ | 59.31$^{a–d}$ | 1.01$^{b–e}$ | 0.98$^{d,e}$ |
| 50 wk | 91.06 | 127.31$^{a}$ | 2.17$^{b,c}$ | 58.76$^{c,d}$ | 1.17$^{a–d}$ | 0.79$^{d,e}$ |
| 60 wk | 81.18 | 123.19$^{a,b}$ | 2.18$^{b}$ | 56.87$^{d}$ | 1.93$^{a}$ | 0.22$^{e}$ |
| FR 20 wk | 69.66 | 124.31$^{a,b}$ | 2.84$^{a}$ | 48.85$^{e}$ | 0.69$^{b–e}$ | 2.05$^{c,d}$ |
| 30 wk | 96.20 | 120.09$^{b,c}$ | 1.98$^{c–e}$ | 60.88$^{a–c}$ | 0.31$^{e}$ | 2.97$^{b,c}$ |
| 40 wk | 96.03 | 125.19$^{a,b}$ | 1.99$^{b–e}$ | 63.20$^{a}$ | 0.21$^{e}$ | 6.34$^{a}$ |
| 50 wk | 94.35 | 127.96$^{a}$ | 2.03$^{b–e}$ | 62.99$^{a,b}$ | 0.18$^{e}$ | 4.38$^{b}$ |
| 60 wk | 90.12 | 125.37$^{a,b}$ | 2.00$^{b–e}$ | 62.88$^{a,b}$ | 0.37$^{d,e}$ | 0.74$^{d,e}$ |
| SE | 1.93 | 1.26 | 0.04 | 0.77 | 0.17 | 0.34 |
| *P*-value | | | | | | |
| HS | 0.037 | <0.001 | 0.006 | <0.001 | <0.001 | <0.001 |
| A | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| HS × A | 0.062 | <0.001 | <0.001 | 0.010 | 0.012 | <0.001 |

[a–e]values within columns with different superscripts are significantly different ($P < 0.05$).
[1]HS: Housing System, A: Age of hen, HS X A: Housing system and age of hen interaction.
CC: Conventional Cage, EC: Enriched Cage, FR: Free Range system.

FI, EM, and FCR values during the laying period were analyzed using the mixed model (PROC MIXED) procedure for repeated measurements, and the number of cages/pens (replicate of each system) was determined as the random factor in the model. The data of the 5%, 50%, and peak hen day egg production reach day, body weight, bone, and blood parameters were analyzed with a one-way ANOVA (Minitab, 2010) to assess the main effects of the housing systems. Analyses for percentage data were conducted after square root of arc sine transformation of the data. Differences were considered significant at $P \leq 0.05$. Significant differences among treatment means were determined by Duncan's multiple range test. The non-parametric data (feather, body, and foot score) were analyzed with Wilcoxon scores (Rank Sums) using the PROC NPAR1WAY procedure of SAS (SAS, 2013), and the Kruskal Wallis test was used to determine the differences among housing the systems. The total mortality data was analyzed using chi-square tests to determine the differences among the housing systems. Data are presented as the means ± SE in all of the tables.

## RESULTS

The effects of the housing system and the hen's age on egg production, FI, EM, FCR, and damaged and dirty egg ratios are given in Table 2. The hen day egg production ($P = 0.037$), FI ($P < 0.001$), EM ($P < 0.001$), and dirty egg ratio of hens were higher in the FR system but were similar in the CC and EC systems. The damaged egg ratio was higher in EC system than CC and FR system ($P < 0.001$). The FCR was found higher in the FR system but was lower in the CC system ($P = 0.006$).

As expected, the investigated values changed throughout the laying period; the age of hens effected hen day egg production, FI, EM, FCR, damaged egg ratio, and dirty egg ratio in all systems ($P < 0.001$, Table 2). The hen day egg production increased with the age of the hen until 30 wk but then decreased ($P < 0.001$). The lowest EM, FI and highest FCR were found at 20 wk of age ($P < 0.001$). The highest damaged egg ratio and lowest dirty egg ratio were found at 60 wk of age ($P < 0.001$).

**Table 3.** The mean values of body weight, hen day egg production age parameters, and mortality of hens in different housing systems.

| Parameters | Housing System[1] | | | *P* |
|---|---|---|---|---|
| | CC | EC | FR | |
| Initial body weight (kg) | 1.41 ± 0.01 | 1.42 ± 0.00 | 1.40 ± 0.00 | 0.178 |
| Final body weight (kg) | 1.95 ± 0.03[b] | 1.94 ± 0.03[b] | 2.09 ± 0.02[a] | <0.001 |
| 5% HD egg production age (d) | 140.0 ± 0.00[a,b] | 138.3 ± 1.75[b] | 145.3 ± 1.75[a] | 0.018 |
| 50% HD egg production age (d) | 154.0 ± 0.00[b] | 154.0 ± 0.00[b] | 159.25 ± 1.75[a] | 0.007 |
| Peak HD egg production age (d) | 199.5 ± 3.50 | 192.5 ± 8.33 | 203.0 ± 9.04 | 0.609 |
| Mortality (%) | 1.25[b] | 6.25[a] | 1.88[b] | 0.020 |

[a,b]within row, values with different superscript letters differ significantly ($P < 0.05$).
[1]CC: Conventional Cage, EC: Enriched Cage, FR: Free Range System.

**Table 4.** The mean values of feather, body, and foot score of hens in different housing systems.

| Parameters | Housing system[1] | | | *P* |
|---|---|---|---|---|
| | CC | EC | FR | |
| Feather score[2] | | | | |
| Neck | 1.73 ± 0.12[c] | 2.33 ± 0.17[b] | 3.28 ± 0.12[a] | <0.001 |
| Breast | 2.08 ± 0.15[b] | 2.03 ± 0.15[b] | 2.78 ± 0.11[a] | <0.001 |
| Vent | 3.80 ± 0.09[a] | 3.38 ± 0.15[b] | 3.75 ± 0.09[a,b] | 0.021 |
| Back | 3.20 ± 0.15[a] | 2.55 ± 0.19[b] | 3.23 ± 0.13[a] | 0.003 |
| Wings | 2.58 ± 0.11[b] | 2.60 ± 0.09[b] | 3.40 ± 0.12[a] | <0.001 |
| Tail | 2.53 ± 0.12[b] | 2.78 ± 0.12[b] | 3.75 ± 0.07[a] | <0.001 |
| Total | 15.90 ± 0.51[b] | 15.65 ± 0.68[b] | 20.18 ± 0.32[a] | <0.001 |
| Mean | 2.59 ± 0.09[b] | 2.66 ± 0.12[b] | 3.45 ± 0.06[a] | <0.001 |
| Body score | | | | |
| Body wound[3] | 2.81 ± 0.06[b] | 2.64 ± 0.06[a] | 2.80 ± 0.03[b] | 0.038 |
| Bumble foot[3] | 2.98 ± 0.02[a] | 3.00 ± 0.00[a] | 2.50 ± 0.09[b] | <0.001 |
| Footpad lesions[4] | 3.00 ± 0.00[a] | 3.00 ± 0.00[a] | 2.78 ± 0.07[b] | <0.001 |
| Claw length (mm) | 16.31 ± 0.22[a] | 15.01 ± 0.30[b] | 12.59 ± 0.15[c] | <0.001 |

[a–c]within row, values with different superscript letters differ significantly ($P < 0.05$).
[1]CC: Conventional Cage, EC: Enriched Cage, FR: Free Range System.
[2]score for feather condition ranged from 1 to 4, with 4 signifying no damage to feathers and 1 signifying severe damage.
[3]score for body wound and bumble foot ranged from 1 to 3, with 3 signifying no lesions on body and foot and 1 signifying severe damage.
[4]score for footpad lesions ranged from 1 to 3, with 3 signifying healthy, normal feet and 1 represented severe hyperkeratosis.

The interaction (housing system × hen age) was significant for FI, FCR, dirty egg ratio (all in $P < 0.001$), EM ($P = 0.010$), and damaged egg ratio ($P = 0.012$, Table 2). The housing system and age interaction resulted in a higher FI of hens in the FR system at 20 wks of age ($P < 0.001$). The highest EM was found in FR hens at 50 and 60 wk of age ($P = 0.010$). The highest FCR was in the FR system at 20 wk of age ($P < 0.001$). The damaged egg ratio was low in FR system at 60 wk of age ($P = 0.012$). On the other hand, the dirty egg ratio was higher in the FR system at 40 and 50 wk of age ($P < 0.001$).

The mean body weight, hen day egg production age parameters, and mortality of layers in different housing systems are given in Table 3. The final body weight and EM were higher in the FR system hens and similar in the CC and EC system hens ($P < 0.001$). The earliest 5% egg production age occured in the EC system hens but was latest in the FR system hens ($P = 0.018$), and the 50% egg production age was similar in the CC and EC system hens and earlier than the FR system hens ($P = 0.007$). However, the peak egg production age was similar in all of the system hens ($P > 0.05$). The mortality ratio was higher in EC system hens (6.25%) than in the CC (1.25%) and FR (1.88%) system hens ($P = 0.020$).

The mean values of feather, body, and foot scores of layers in different housing systems are given in Table 4. The mean feather score values were similar in the CC and EC system hens, but the best feather score was found in the FR system hens ($P < 0.001$). Hens in the EC system had more body wounds than in the other systems ($P = 0.038$). The bumble foot and footpad lesions were similar in the CC and EC system hens, but were the worst in the FR system hens ($P < 0.001$). The shortest claw length was in the FR systems hens ($P < 0.001$).

The effects of different housing systems on the values of tibia parameters are given in Table 5. The tibia weight was significantly different among hens from the 3 housing systems. The lowest tibia weight was found in the CC system hens ($P = 0.021$). The tibia length was similar in the CC and EC systems but was shorter in the FR system hens ($P < 0.001$). The highest tibia

**Table 5.** The mean values of tibia parameters of hens in different housing systems.

| | Housing system[1] | | | |
|---|---|---|---|---|
| Parameters | CC | EC | FR | *P* |
| Weight (g) | 8.62 ± 0.16[b] | 9.15 ± 0.15[a,b] | 9.29 ± 0.19[a] | 0.021 |
| Length (mm) | 127.85 ± 0.65[a] | 128.60 ± 0.5[a] | 125.76 ± 0.39[b] | 0.001 |
| Cortical area ($mm^2$) | 1.26 ± 0.05 | 1.33 ± 0.07 | 1.33 ± 0.09 | 0.730 |
| *WLI (mg/mm) | 67.36 ± 1.00[b] | 71.13 ± 1.14[a,b] | 73.82 ± 1.48[a] | 0.002 |
| Tibia breaking strength (kg) | 8.59 ± 0.63[b] | 8.63 ± 0.73[b] | 12.23 ± 0.57[a] | <0.001 |
| Dry matter (%) | 76.19 ± 1.19 | 78.75 ± 1.79 | 79.75 ± 1.58 | 0.252 |
| Ash (%) | 55.31 ± 0.82 | 55.42 ± 0.62 | 56.40 ± 0.76 | 0.523 |
| Ca (%) | 22.66 ± 0.54 | 23.32 ± 0.37 | 22.98 ± 0.39 | 0.568 |
| P (%) | 9.57 ± 0.20 | 9.89 ± 0.18 | 9.74 ± 0.16 | 0.464 |

[a,b]within row, values with different superscript letters differ significantly ($P < 0.05$).
[1]CC: Conventional Cage, EC: Enriched Cage, FR: Free Range System.
*WLI: Tibia Weight Length Index.

**Table 6.** The mean values of tonic immobility and blood parameters of hens in different housing systems.

| | Housing system[1] | | | |
|---|---|---|---|---|
| Parameters | CC | EC | FR | *P* |
| Induction number | 2.58 ± 0.21 | 2.50 ± 0.20 | 2.08 ± 0.23 | 0.236 |
| Tonic immobility | 152.0 ± 67.69 | 217.4 ± 75.29 | 215.1 ± 50.95 | 0.727 |
| H/L (%) | 0.61 ± 0.06[a] | 0.46 ± 0.03[b] | 0.41 ± 0.04[b] | 0.006 |
| Heterophil (%) | 34.20 ± 2.40[a] | 29.00 ± 1.24[a,b] | 26.67 ± 1.40[b] | 0.014 |
| Lymphocyte (%) | 58.80 ± 2.21[b] | 64.50 ± 1.46[a,b] | 66.50 ± 1.56[a] | 0.012 |
| Monocyte (%) | 3.60 ± 0.33 | 3.33 ± 0.28 | 3.50 ± 0.43 | 0.867 |
| Eosinophil (%) | 1.60 ± 0.33 | 1.33 ± 0.28 | 1.83 ± 0.30 | 0.516 |
| Basophil (%) | 1.80 ± 0.30 | 1.83 ± 0.17 | 1.50 ± 0.26 | 0.582 |
| Glucose (mg/dL) | 222.3 ± 8.90 | 217.8 ± 5.86 | 239.7 ± 4.69 | 0.064 |
| Total cholesterol (mg/dL) | 136.1 ± 13.16 | 133.3 ± 12.05 | 122.4 ± 9.51 | 0.686 |
| Triglyceride (mg/dL) | 905.5 ± 60.26 | 1,043.3 ± 23.44 | 931.3 ± 54.83 | 0.122 |
| Ca (mg/dL) | 26.28 ± 1.04 | 26.80 ± 0.44 | 27.98 ± 0.63 | 0.270 |
| P (mg/dL) | 5.59 ± 0.35[b] | 5.94 ± 0.33[b] | 6.98 ± 0.27[a] | 0.013 |

[a,b]within row, values with different superscript letters differ significantly ($P < 0.05$).
[1]CC: Conventional Cage, EC: Enriched Cage, FR: Free Range System.

breaking strength was found in FR system hens compared with in CC and EC system hens ($P < 0.001$). The WLI of the tibia was lower in the CC system hens ($P = 0.002$). The tibia cortical area, dry matter, ash, Ca, and P contents were found to be similar in all housing systems hens ($P > 0.05$).

The mean values of TI and blood parameters of layers in different housing systems are given in Table 6. The highest H/L ratio was found in the CC system when compared to EC and FR system hens ($P = 0.006$). The highest blood P level was found in the FR system ($P = 0.013$). But the tonic immobility, blood glucose, total cholesterol, triglyceride, and Ca values of hens were found similar in CC, EC, and FR systems hens ($P > 0.05$).

## DISCUSSION

In poultry rearing today, in addition to high production values, housing the hens while promoting good welfare is becoming mandatory. Growing consumer perception for healthy eggs laid by free range or organic reared hens should also be taken into account. Therefore, studies on the effects of new housing trends both for hen welfare and production parameters are continuing. Many researchers have reported that egg production of hens in conventional cage, enriched cage, aviary, and barn systems were found to be similar (Neijat et al., 2011; Ahammed et al., 2014) and some have reported that egg production was higher in conventional cage systems than in aviary, floor management, or free range systems (Tauson et al., 1999; Leyendecker et al., 2001). In the present small scale study, hen day egg production was found to be higher in the FR system but was similar in the CC and EC systems.

According to Leyendecker et al. (2001), white layer (Lohmann LSL) and Brown layer (Lohmann LT) hens in free range system had a poorer feed conversion in comparison with cage and aviary pens. Also the comparison of conventional and enriched cage systems had a significant effect on FCR results. Different studies with Hisex Brown hen layers (Englmaierova et al., 2014) and with Lohmann LSL and Lohman Brown Classic hen layers (Onbaşilar et al., 2015) also adressed the

effect of housing system on FCR results. Ahammed et al. (2014) observed that Lohmann Brown hens in a barn system had a higher feed intake and feed conversion ratio than conventional cage and aviary system. In the present study highest FI and FCR were found in the FR system and it is possible that the hens in the FR system had higher locomotor activity and as a result of this activity, might have consumed more feed.

The previously published results have reported that egg mass is affected by the rearing systems (Hidalgo et al., 2008; Tactacan et al., 2009; Onbaşilar et al., 2015). The body weight of hens in the floor system were found to be higher compared to the ones in the caged systems (Singh et al., 2009). In the present study, hens reared in the FR system had higher final body weight than the CC and EC reared hens and they laid larger eggs. Thus, there is a positive correlation between body weight and egg weight of layers (Zhang et al., 2005).

Some researchers reported that the ratio of damaged egg was higher in furnished/enriched cages than in conventional cages (Abrahamsson and Tauson, 1997; Wall et al., 2002). However, Hidalgo et al. (2008) found that the damaged egg ratio was not different in cage, free range, barn, and organic systems. In the present study, the damaged egg ratio was the highest in the EC system eggs. This might be a result of the fact that egg collection occured once a day and the distance between the nesting area and egg belt may have increased the risk of collisions of eggs.

The dirty eggs were a problem in the free range systems, and the main factors affecting this results are the soiling of nests or egg laying on a litter (Leyendecker et al., 2001; Sosnowka-Czajka et al., 2010). In the present study, the dirty egg ratio was higher in the FR system than in cage systems, especially in the last stage of the production period of the hens. It is possible that rainy weather conditions during this production period increased the ratio of dirty eggs in the FR system.

Sherwin et al. (2010), with a commercial scale research project, reported that the mortality rate was lower in enriched/furnished cages than in barn, free range, and conventional cage systems. There is an association between perches in furnished/enriched cages and increased cloacal cannibalism risk for ISA brown layers (Moinard et al., 1998). In the present study mortality ratio was higher in the EC system hens than in the CC and FR system hens, and deaths in the EC system were mostly due to cloacal cannibalism of hens.

The hens in furnished/enriched cages have better feather conditions than those in conventional cage systems (Tauson and Abrahamsson, 1997). However, Tactacan et al. (2009) observed that the feather condition of Shaver White layer strain hens did not differ in the conventional cage and enriched cage systems. In the present study, the best feather score was found in the FR system hens but the hens housed in the CC and EC systems appear to have similar feather cover. This result is similar to the findings reported by Blatchford et al. (2016).

The housing conditions and litter quality are important factors for bumble foot and footpad lesions (Wang et al., 1998) and foot health is better in cage systems than in litter or free range systems (Tauson et al., 2005; Blatchford et al., 2016). Also excessive claw length and broken claws can be a problem for hens and can occur without access to nail trimming material in cages (Hester et al., 2013; Blatchford et al., 2016). In the present study, bumble foot and footpad lesion values were similar in the CC and EC system hens, but higher bumble foot and footpad lesions were found in the FR system hens. The longest claw length was found in the CC system hens when compared to EC and FR system hens. This is in agreement with the findings of Blatchford et al. (2016) who observed that conventional cage system hens had longer claws than those in enriched cage and aviary systems.

The bone breaking strength, bone ash weight, and bone mineral content in general are used to evaluate the bone status (Park et al., 2003). Bone weakness is an important issue for the egg layer industry because of the consequent pain for hens and it is also negatively affects the egg production performance (Webster, 2004). In the aviary system, hens had shorter tibia, greater bone width and cortical thickness compared to those kept in a conventional cage system (Regmi et al., 2015). In the present study the highest tibia weight, shortest tibia length, and stronger tibia were found in the FR system hens. It is possible that hens in the FR systems had higher locomotor activity and their bones might become stronger, as supported by Silversides et al. (2012) who found higher bone strength in floor pen reared hens compared to cage reared hens. Also there were no difference for tibia ash weight and the percentage of the Ca and P contents of Shaver White layers in the CC and EC systems (Tactacan et al., 2009), but hens that are housed in floor pens have a higher tibia weight, ash weight, and ash percentage compared to those were housed in cage systems (Silversides et al., 2012). However, in the present study, tibia dry matter, ash, Ca, and P contents of hens in the CC, EC, and FR systems were found to be similar.

The TI, a reliable measure for the fear level of hens, can be used as an indicator of the welfare status of hens in different housing conditions (Ferrante et al., 2009). If a certain housing style provides a more or less stressful environment this is reflected in the hematology results, such as an increased H/L ratio of birds (Davis et al., 2008). Thus, Shini (2003) observed a higher H/L ratios of hens in conventional cage compared to hens in modified cage and free range systems. In the present study, although tonic immobility durations of hens were found to be similar in all housing systems, the highest H/L ratio was found in the CC system when compared to EC and FR systems.

The blood glucose, cholesterol, and triglyceride levels are used for stress indicators of hens and there have

been studies on blood glucose, cholesterol, and triglyceride levels, as well as Ca and P contents of hens in different housing systems (Pavlik et al., 2007; Pavlik et al., 2009). In the present study, the blood glucose, total cholesterol, triglyceride, and Ca contents of hens were found to be similar in CC, EC, and FR systems.

The development of housing systems, such as enriched cages or free range systems, for layers has led to improvements, and welfare issues are the main impetus behind this development (Lay et al., 2011). The alternative housing systems, designed to allow hens to express more natural behavior and have more freedom of movement, are becoming widespread. Experimental studies allow us to understand the effects of housing systems on the performance and welfare of hens. In conclusion, based on the results of this small scale experimental study, the production performance, final live weight, tibia breaking strength, mean feather score, and foot lesions of laying hens were found to be similar between the conventional and enriched cages, but were different in the free range system. In the free range system, hens had better feather and bone traits, but the dirty egg ratio, feed consumption, and foot lesions were higher than in the cage systems. On the other hand, hens in the FR systems had more additional space for optimum comfort and welfare.

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## REFERENCES

Abrahamsson, P., and R. Tauson. 1997. Effect of group size on performance, health and birds' use of facilities in furnished cages for laying hens. Acta Agr. Scand. A- An. 47:254–260.

Ahammed, A., B. J. Chae, J. Lohakare, B. Keohavong, M. H. Lee, S. J. Lee, D. M. Kim, J. Y. Lee, and S. J. Ohh. 2014. Comparison of aviary, barn and conventional cage raising of chickens on laying performance and egg quality. Asian-Austral. J. Anim. 27:1196–1203.

AOAC International. 2005. Official Methods of Analysis of the AOAC International. 18th Ed. AOAC Int., Gaithersburg, MD.

Appleby, M. C. 1998. The Edinburgh modified cage: Effects of group size and space allowance on brown laying hens. J. Appl. Poult. Res. 7:152–161.

Araujo, G. M., J. H. V. D. Silva, F. M. Vieites, G. H. K. D. Moraes, R. B. D. Souza, A. D. A. Barbosa, and J. G. Caramori, Jr. 2012. Anionic variation of diets on bone characteristics of broilers at 7 and 14 days of age. Rev. Bras. Zootecn. 41:2124–2128.

Asselt, E. D. Van, L. G. J. van Bussel, P. van Horne, H. van der Voet, G. W. A. M. van der Heijden, and H. J. van der Fels-Klerx. 2015. Assessing the sustainability of egg production systems in The Netherlands. Poult. Sci. 94:1742–1750.

Blatchford, R. A., R. M. Fulton, and J. A. Mench. 2016. The utilization of the Welfare Quality® assessment for determining laying hen condition across three housing systems. Poult. Sci. 95:154–163.

Clark, P., W. Boardman, and S. Raidal. 2009. Atlas of Clinical Avian Hematology. p. 200, Wiley Publishing Inc., John Wiley & Sons, West Sussex, UK.

Crenshaw, T. D., E. R. Peo, Jr., A. J. Lewis, and B. D. Moser. 1981. Bone strength as a trait for assessing mineralization in swine: A critical review of techniques involved. J. Anim. Sci. 53:827–835.

Crenshaw, T. D. 1986. Reliability of dietary Ca and P and bone mineral contents as predictors of bone mechanical properties at various time periods in growing swine. J. Nutr. 116:2155–2170.

Davis, A. K., D. L. Maney, and J. C. Maerz. 2008. The use of leukocyte profiles to measure stress in vertebrates: A review for ecologists. Funct. Ecol. 22:760–772.

Ekstrand, C., T. E. Carpenter, I. Andersson, and B. Algers. 1998. Prevalence and control of foot-pad dermatitis in broilers in Sweden. Brit. Poult. Sci. 39:318–324.

Englmaierova, M., E. Tumova, V. Charvatova, and M. Skrivan. 2014. Effects of laying hens housing system on laying performance, egg quality characteristics, and egg microbial contamination. Czech J. Anim. Sci. 59:345–352.

Ferrante, V., S. Lolli, G. Vezzoli, and L. G. Cavalchini. 2009. Effects of two different rearing systems (organic and barn) on production performance, animal welfare traits and egg quality characteristics in laying hens. Italian J. Anim. Sci. 8:165–174.

Ghareeb, K., W. A. Awad, O. E. Sid-Ahmed, and J. Bohm. 2014. Insights on the host stress fear and growth responses to the deoxynivalenol feed contaminant in broiler chickens. Plos One 9:E87727. Doi:10.1371/Journal.Pone.0087727.

Hester, P. Y., S. A. Enneking, K. Y. Jefferson-Moore, M. E. Einstein, H. W. Cheng, and D. A. Rubin. 2013. The effect of perches in cages during pullet rearing and egg laying on hen performance, foot health, and plumage. Poult. Sci. 92:310–320.

Hidalgo, A., M. Rossi, F. Clerici, and S. Ratti. 2008. A market study on the quality characteristics of eggs from different housing systems. Food Chem. 106:1301–1308.

Jones, D. R., D. M. Karcher, and Z. Abdo. 2014. Effect of a commercial housing system on egg quality during extended storage. Poult. Sci. 93:1282–1288.

Karcher, D. M., D. R. Jones, Z. Abdo, Y. Zhao, T. A. Shepherd, and H. Xin. 2015. Impact of commercial housing systems and nutrient and energy intake on laying hen performance and egg quality parameters. Poult. Sci. 94:485–501.

Lay, D. C., Jr., R. M. Fulton, P. Y. Hester, D. M. Karcher, J. Kjaer, J. A. Mench, B. A. Mullens, R. C. Newberry, C. J. Nicol, N. P. O'Sullivan, and R. E. Porter. 2011. Hen welfare in different housing systems. Poult. Sci. 90:278–294.

Leyendecker, M., H. Hamann, J. Hartung, J. Kamphues, C. Ring, G. Glünder, C. Ahlers, I. Sander, U. Neuman, and O. Distl. 2001. Analysis of genotype environment interactions between layer lines and housing systems for performance traits, egg quality and bone breaking strength: 1st communication: performance traits. Züchtungskunde. 73:290–307.

Mench, J. A., D. A. Summer, and J. T. Rosen-Molina. 2011. Sustainability of egg production in the United States-The policy and market context. Poult. Sci. 90:229–240.

Miao, Z. H., P. C. Glatz, and Y. J. Ru. 2005. Free-range poultry production - A review. Asian-Aust. J. Anim. Sci. 18:113–132.

Minitab. 2010. Minitab V.16.1.0, Minitab Institute Inc., UK.

Moinard, C., J. P. Morisse, and J. M. Faure. 1998. Effect of cage area, cage height and perches on feather condition, bone breakage and mortality of laying hens. Brit. Poult. Sci. 39:198–202.

Neijat, M., J. D. House, W. Guenter, and E. Kebreab. 2011. Production performance and nitrogen flow of Shaver White layers housed in enriched or conventional cage systems. Poult. Sci. 90:543–554.

National Research Council. 1994. Nutrient Requirements of Poultry. 9th rev. ed. Natl. Acad. Press, Washington, DC.

Onbaşilar, E. E., N. Ünal, E. Erdem, A. Kocakaya, and B. Yaranoğlu. 2015. Production performance, use of nest box, and external appearance of two strains of laying hens kept in conventional and enriched cages. Poult. Sci. 94:559–564.

Park, S. Y., S. G. Birkhold, L. F. Kubena, D. J. Nisbet, and S. C. Ricke. 2003. Effect of storage condition on bone breaking strength amd bone ash in laying hens at different stages in production cycles. Poult. Sci. 82:1688–1691.

Pavlik, A., M. Pokludova, D. Zapletal, and P. Jelinek. 2007. Effects of housing systems on biochemical indicators of blood plasma in laying hens. Acta Vet. Brno. 76:339–347.

Pavlik, A., M. Lichovnikova, and P. Jelinek. 2009. Blood plasma mineral profile and qualitative indicators of the eggshell in laying hens in different housing systems. Acta Vet. Brno. 78:419–429.

Regmi, P., T. S. Deland, J. P. Steibel, C. I. Robison, R. C. Haut, M. W. Orth, and D. M. Karcher. 2015. Effect of rearing environment on bone growth of pullets. Poult. Sci. 94:502–511.

Rodenburg, T. B., F. A. Tuyttens, K. De Reu, L. Herman, J. Zoons, and B. Sonck. 2008. Welfare assessment of laying hens in furnished cages and non-cage systems: An on-farm comparison. Anim. Welf. 17:363–373.

SAS. 2013. A User's Guide to SAS V9.4. SAS Institute, Inc. Cary, NC.

Sherwin, C. M., G. J. Richards, and C. J. Nicol. 2010. A comparison of the welfare or layer hens in four housing systems in the UK. Brit. Poult. Sci. 51: 488–99.

Shini, S. 2003. Physiological responses of laying hens to the alternative housing systems. Int. J. Poult. Sci. 2:357–360.

Silversides, F. G., R. Singh, K. M. Cheng, and D. R. Korver. 2012. Comparison of bones of 4 strains of laying hens kept in conventional cages and floor pens. Poult. Sci. 91:1–7.

Singh, R., K. M. Cheng, and F. G. Silversides. 2009. Production performance and egg quality of four strains of laying hens kept in conventional cages and floor pens. Poult. Sci. 88:256–264.

Sosnowka-Czajka, E., E. Herbut, and I. Skomorucha. 2010. Effect of different housing systems on productivity and welfare of laying hens. Ann. Anim. Sci. 10:349–360.

Tactacan, G. B., W. Guenter, N. J. Lewis, J. C. Rodriguez-Lecompte, and J. D. House. 2009. Performance and welfare of laying hens in conventional and enriched cages. Poult. Sci. 88:698–707.

Tauson, R., A. Wahlström, and P. Abrahamsson. 1999. Effect of two floor housing systems and cages on health, production, and fear response in layers. J. Appl. Poult. Res. 8:152–159.

Tauson, R., J. Kjaer, G. A. Maria, R. Cepero, and K. E. Holm. 2005. Applied scoring of integument and health in laying hens. Proc. 7th European Symp. Poultry Welfare, Lublin, Poland, 15–19, June 2005. Anim. Sci. Papers and Reports, 23(Suppl.1):153–159.

Wall, H., R. Tauson, and K. Elwinger. 2002. Effect of nest design, passages and hybrid on use of nest and production performance of layers in furnished cages. Poult. Sci. 81:333–339.

Wang, G., C. Ekstrand, and J. Svedberg. 1998. Wet litter and perches as risk factors for the development of foot-pad dermatitis in floor housed hens. Brit. Poult. Sci. 39:191–197.

Webster, A. 2004. Welfare implications avian osteoporosis. Poult. Sci. 83:184–192.

Zhang, L. C., Z. H. Ning, G. Y. Xu, Z. C. Hou, and N. Yang. 2005. Heritabilities and genetic and phenotypic correlations of egg quality trans in Brown egg dwarf layers. Poult. Sci. 84:1209–1213.